

Geologic Site of the Month
September, 2007

***The U.S. Route 1/State Route 3 Roadcut at the
Approach to the Penobscot Narrows Bridge***



44 33' 37.66" N, 68 48' 26.53" W

Text by
Marc Loiselle



Introduction

The construction of the new Penobscot Narrows bridge to replace the aging bridge that connected Prospect to Verona Island since the 1930's involved re-routing of U.S. Route 1/State Route 3 (Figure 1) approximately 200 feet to the west of its former track. The fact that it was 200 feet of solid rock ranging close to one hundred feet high was only a minor inconvenience, and the completion of the approach to the new bridge created a spectacular roadcut in the Ordovician Penobscot Formation. Aerial photographs of the approach to the Penobscot Narrows bridge before and after. The top photograph was taken in 2004; the bottom photograph in 2006 before the center span of the bridge was completed.



Figure 1. Aerial photos of the area.



Introduction

This roadcut is September's site-of-the-month. Figure 2 is a topographic map showing the location of the new bridge and Fort Point State Park in Stockton Springs where other outcrops discussed below can be found.

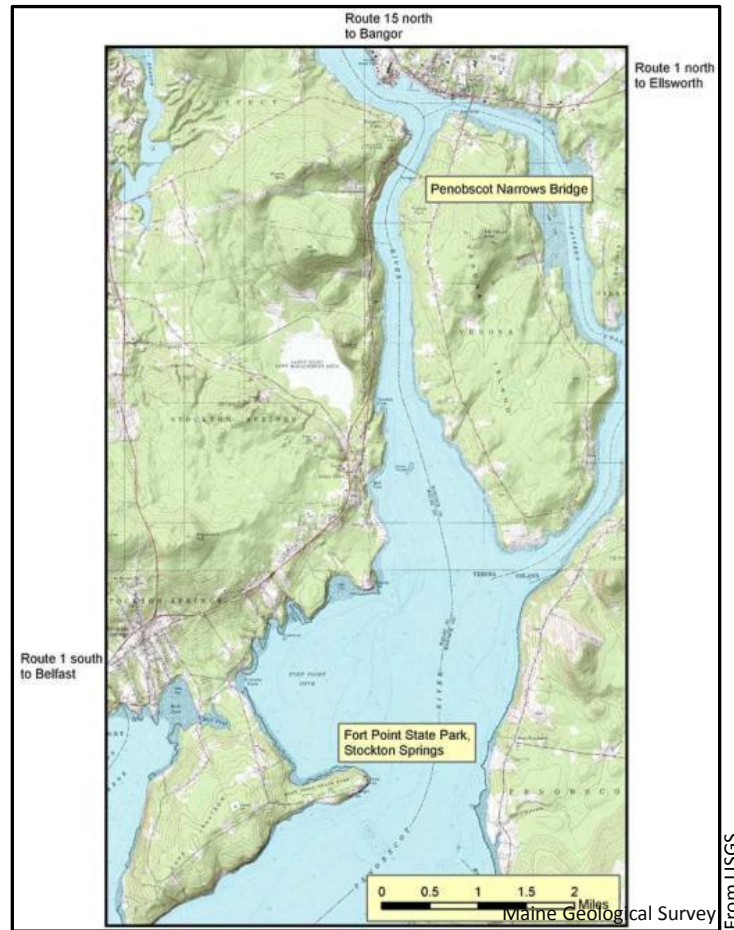


Figure 2. U.S. Geological Survey topographic map of a portion of northern Penobscot.



Geologic background

In a discussion of the geology of the State by C.H. Hitchcock in Colby's Atlas of the State of Maine (5th edition, 1884), he assigns the belt of rocks "...from Castine northerly, bordering the granite, a flinty slate and quartzite, some of them suggestive of the St. John's group" to the Huronian (Precambrian) or Cambrian ([See Hitchcock's 1885 map](#)). Being of no economic significance, no further mention was made of the nature of these rocks, but they included the present day Penobscot Formation. The Penobscot Formation was defined by Smith, Bastin, and Brown (1907, page 4):

"The Penobscot formation is composed of metamorphosed shaly sediments which are typically developed along nearly the whole length of the western shore of Penobscot Bay. They occupy large areas west of the Penobscot Bay quadrangle, between the ocean and the Kennebec River. The most typical exposures of this formation occur in the northwestern part of the quadrangle, between Belfast Bay and Sandy Point. The sedimentary character of the rocks is shown by the presence of distinct bedding at many localities..."

... In color the rocks of this formation vary from light gray through steel-gray and purplish gray to black, the darker grays being predominant. The weathered surfaces are usually rusty. In a few places, as at Fort Point, the rock exhibits a very perfect slaty cleavage which is highly inclined to the bedding planes..."

... The relations between the Penobscot slate and rocks other than granite and diorite are not shown within the limits of this quadrangle, but are well exhibited on the point east of Rockport Harbor, in the Rockland Quadrangle. Here, the Penobscot Formation overlies directly and conformably the Battie quartzite."

...and, on the basis of this relationship they assigned the formation to the Cambrian.



Geologic background

Keith incorporated much of the Smith, Bastin, and Brown (1907) work on his [1933 map](#). He did modify the extent of the Cambrian-Ordovician rocks mapped by Smith, Bastin and Brown as Penobscot Formation (sometimes correctly, sometimes not), but kept the defining "type area" along the western side of Penobscot Bay from Belfast through Searport and up the Penobscot River to Bucksport.

The [1967 Preliminary Geologic Map of Maine](#) (Hussey and others, 1967) grouped the older rocks of the Camden-Rockland area and Islesboro with the Penobscot Formation into a single map unit (SO_p), and correlated them with rocks with similar lithologies to the east (Op) - as far east as Calais on the New Brunswick border. Recognizing that the upper portions of the sequence were everywhere in fault contact with younger Silurian-Devonian rocks and that intrusions that cut the sequence were Silurian or younger, the age assignment expanded to include the early Silurian. It is not known why the Cambrian age assignment was dropped.



Geologic background

The 1985 Geologic Map of Maine (Osberg and others, 1985) shows the (again) Ordovician-Cambrian Penobscot Formation as a separate entity extending as far south as Owls Head, through the type area (Belfast Bay to Sandy Point), and (interrupted by Devonian plutons) as far east as Beddington along the Air Line (State Route 9). Similar rocks further to the east are shown as Ordovician-Cambrian Cookson Formation (now the Cookson Group) defined in New Brunswick. Correlation with the fossil-bearing Cookson Group together with geochronologic work returned the age assignment to the Ordovician-Cambrian.

Current thinking (Stewart, 1998, and references therein; Tucker and other, 2001) places the Penobscot Formation in the Ordovician-Cambrian. These rocks were deposited in relatively deep, oxygen-deficient waters along a continental slope concurrently with minor sea floor volcanism, and thrust northwest over Silurian rocks of the Fredericton Trough in the Silurian. The rocks of the Penobscot Formation were complexly deformed and metamorphosed at this time, and possibly underwent regional metamorphism in the late Silurian during an early stage of the Acadian orogeny (West and others, 1995). Parts of the Penobscot Formation were metamorphosed in the contact aureoles of the post-Acadian Devonian plutons such as the Mount Waldo pluton (Stewart, 1998).



Geologic Background

Figure 3 is a portion of Stewart's 1998 geologic map of northern Penobscot Bay. Op and Opi are the rocks of the Penobscot Formation; Dmw is the Devonian Mount Waldo granite and Dwp is the Devonian Wallamatogus pluton.

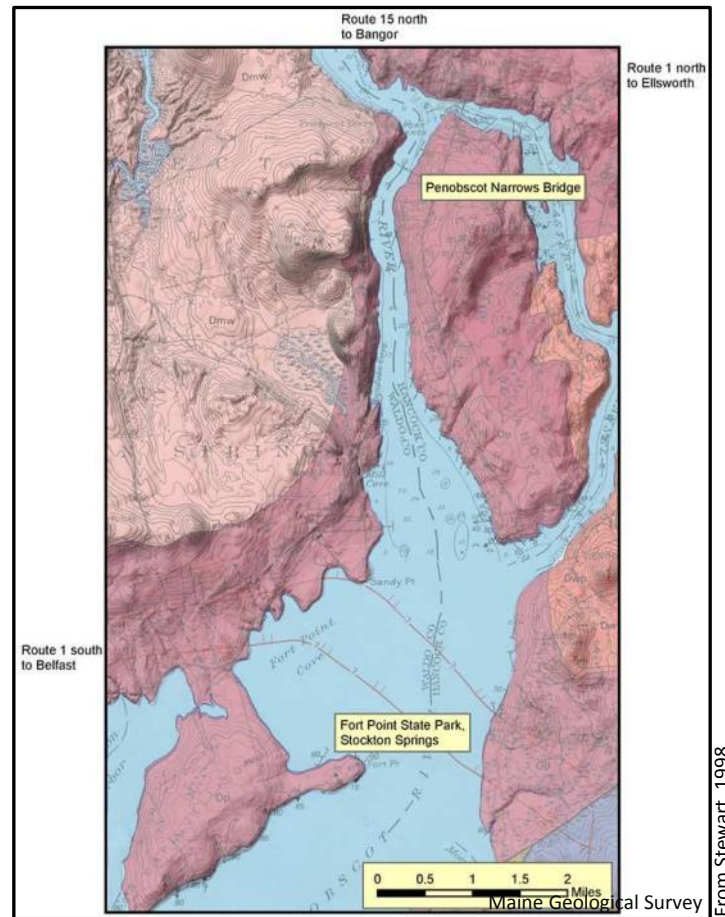


Figure 3. A portion of Stewart's 1998 geologic map of northern Penobscot Bay.



The Roadcut

Figure 4 is a panoramic view of the new roadcut along the approach to the Penobscot Narrows bridge. The view is towards the west; the entrance to Fort Knox State Park and the bridge observation tower is at the extreme right of the image; Routes 1 and 3 southbound disappear around the left edge.

(NOTE: The roadcut appears to be convex towards the east in Figure 4, but, as shown in the aerial photographs above, the roadcut is actually concave to the east. Distance and camera focal length combine to give the impression that the roadcut is convex.)

Sedimentary bedding in the Penobscot Formation at this locality is steeply dipping, striking generally north-northeast to south-southwest. The center of the image is looking almost directly at a bedding surface, along the axial plane of a broad, near-vertical fold.

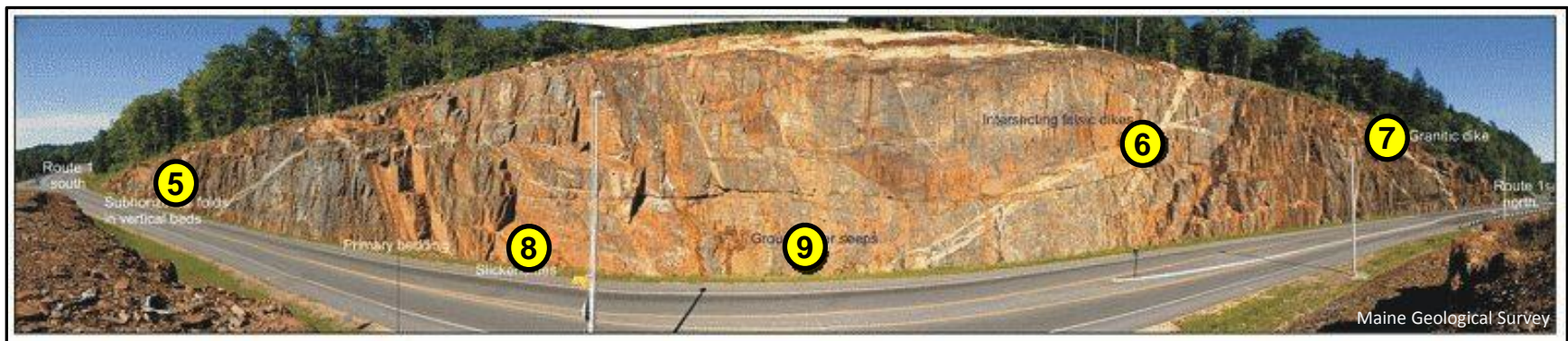


Photo by Marc Loisel

Figure 4. Index map for photographs. Yellow dots are locations of photographs shown in Figures 5-9.



The Roadcut

The dominant folds in the Penobscot Formation are northeast-trending isoclinal folds, so the broad fold in the roadcut is a later fold. At the southern end of the outcrop, late sub-horizontal folds also warp beds of quartzite (Figure 5).

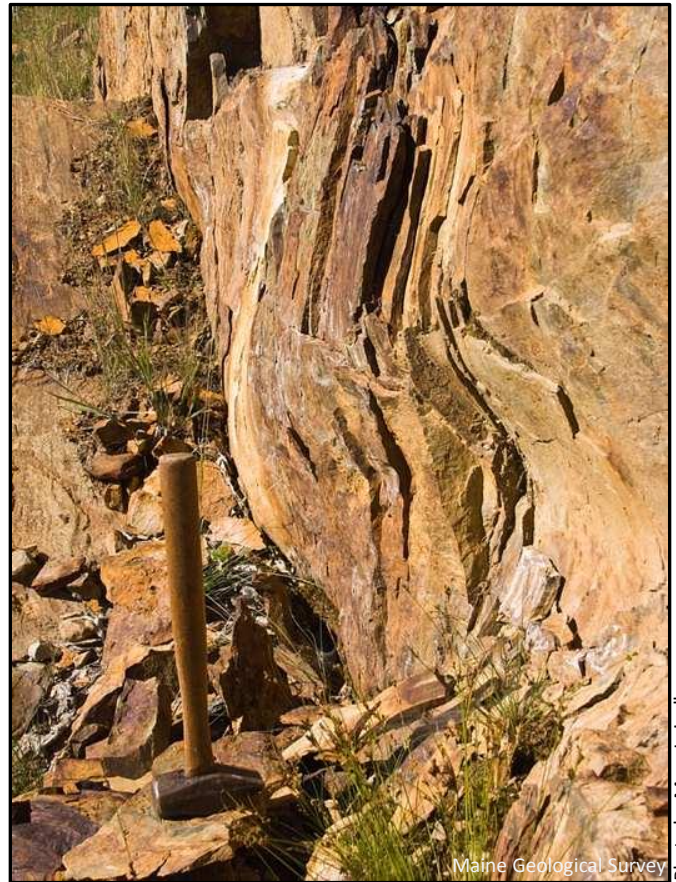


Figure 5. Beds of quartzite gently folded about a sub-horizontal fold axis at the south end of the roadcut.

The Roadcut

The most obvious features in the roadcut are the stripes of light-colored rock, felsic dikes, (Figures 6-7) that intrude the Penobscot Formation. Inclusions of Penobscot Formation are readily visible in the dikes.

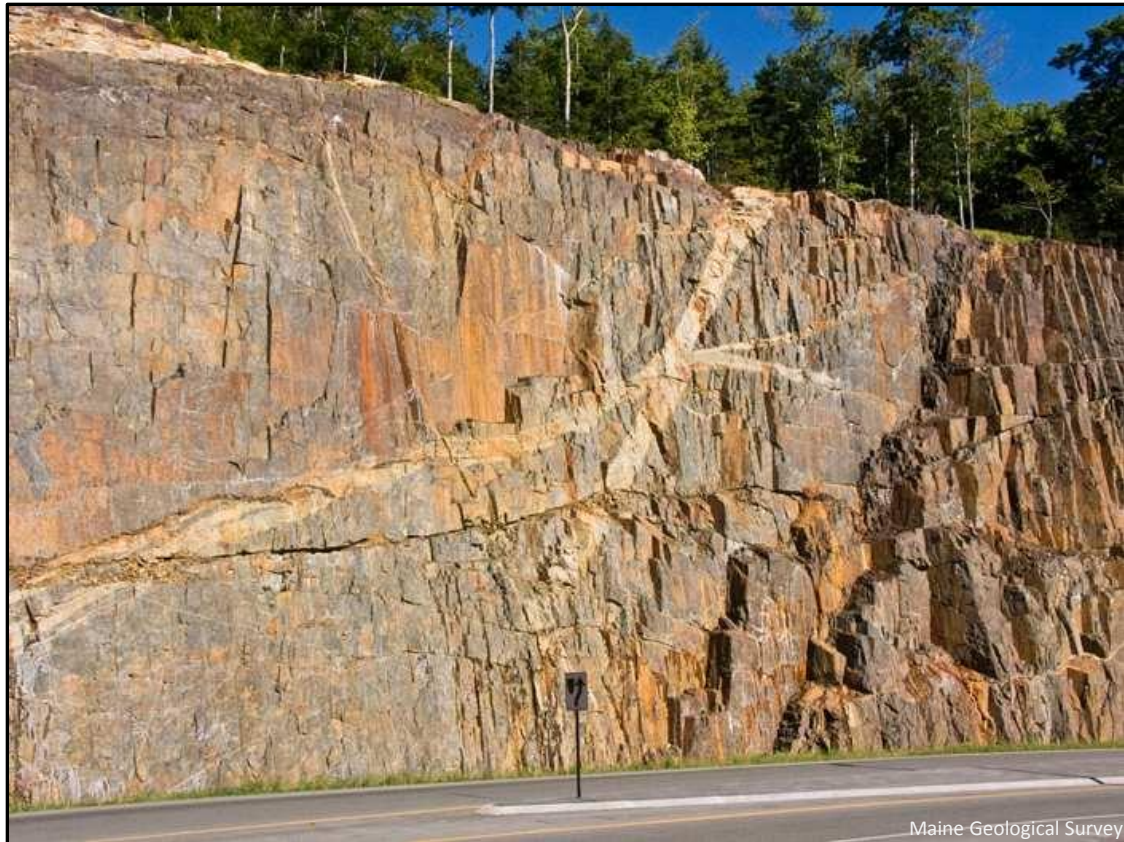


Figure 6. Intersecting felsic dikes of Mount Waldo granite in the Penobscot Formation. The more steeply dipping dike has been cut and offset slightly by the more shallowly dipping dike. Inclusions of Penobscot Formation are visible at the lower left in the younger dike.

The Roadcut

The dikes are most likely Devonian in age and related to the [Mount Waldo pluton](#). The contact with the pluton is less than 100 feet to the west (Figure 3), and exposures of the granite are present just to the south along Routes 1 and 3.

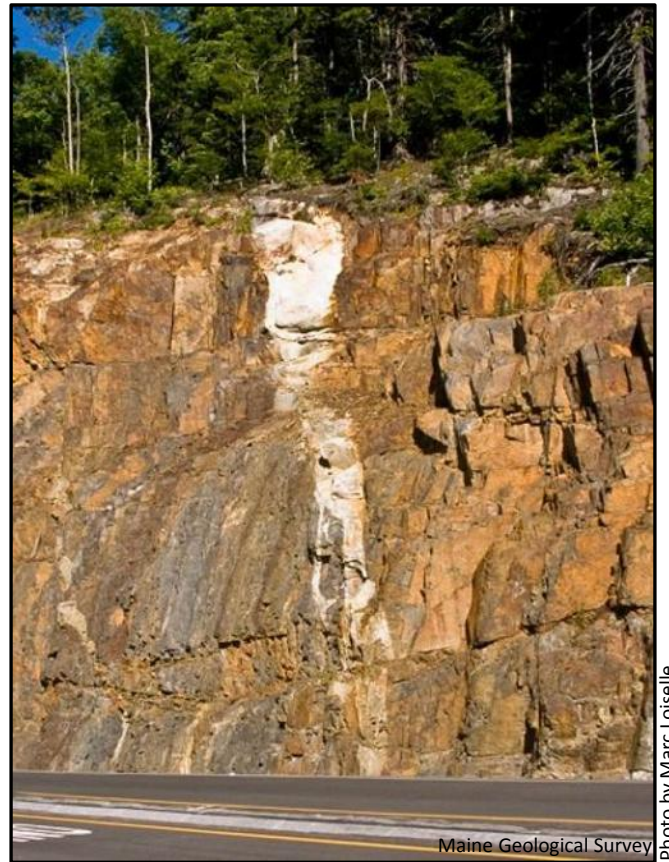


Figure 7. Dike of Mount Waldo granite in the Penobscot Formation. Inclusions of Penobscot Formation are visible in the lower portion of the dike. Note that the dike has not been significantly offset by the later sub-horizontal fracture.

The Roadcut

Another prominent feature is the nearly continuous, apparently sub-horizontal fracture that traverses most of the roadcut. (The fracture only appears sub-horizontal along the face of the roadcut; it most likely has an orientation similar to the joints that dip to the northeast.) The fracture intersects felsic dikes at several places, but displacement of the dikes is minor. The fracture most likely formed due to stress relief during uplift and erosion of the area. While displacement of the felsic dikes is minor, slickensides (Figure 8) produced by motion along a fracture surface are visible on joint surfaces at many places in the outcrop.



Photo by Marc Loiselle

Figure 8. Slickensides on a joint surface in the Penobscot Formation.

The Roadcut

These pictures were taken in early August when groundwater levels are typically near or at seasonal low values, so there is very little groundwater seepage from the fractures. The picture would be very different in late fall or early spring. There is some seepage from fractures (Figure 9) in the lower center of the roadcut.

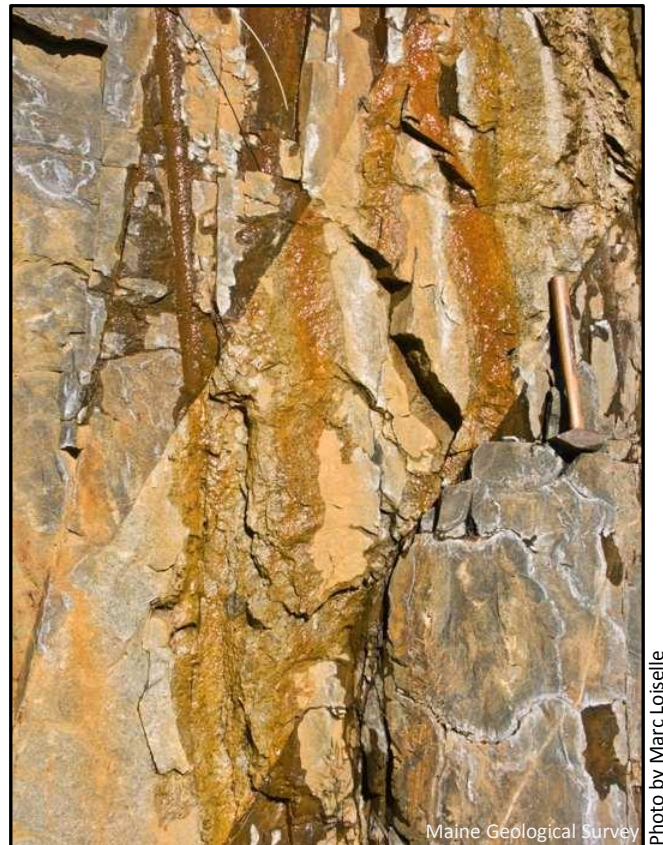


Photo by Marc Loiselle

Figure 9. Groundwater seeps in the Penobscot Formation. Note the irregular pattern of the seepage.

The Roadcut

One thing to note is the irregular pattern of the seepage. A planar fracture that appears continuous in 2-dimensions is not necessarily open in the 3rd dimension. Groundwater flow is through narrow channels along the fracture surface and visible seepage occurs where these channels exit the rock. These channels transmit groundwater to wells drilled in bedrock, the most common source of water for homes in rural Maine. On a larger scale, this irregularity in groundwater flow in the bedrock makes predicting yields in a bedrock well uncertain at best and folly at worst.



The Penobscot Formation at Fort Point State Park, Stockton Springs

Regionally, the Penobscot Formation "tops" towards the south and southeast (Stewart, 1998, and Figure 3). **NOTE: THIS IS A STATE PARK - NO HAMMERS AND NO COLLECTING, PLEASE!** This may be the locality with the "perfect slaty cleavage" mentioned by Smith, Bastin, and Brown (1907, page 4, quoted above). If you poke around and look at vertical surfaces you will see sub-horizontal bedding at high angles to the cleavage as quoted above.

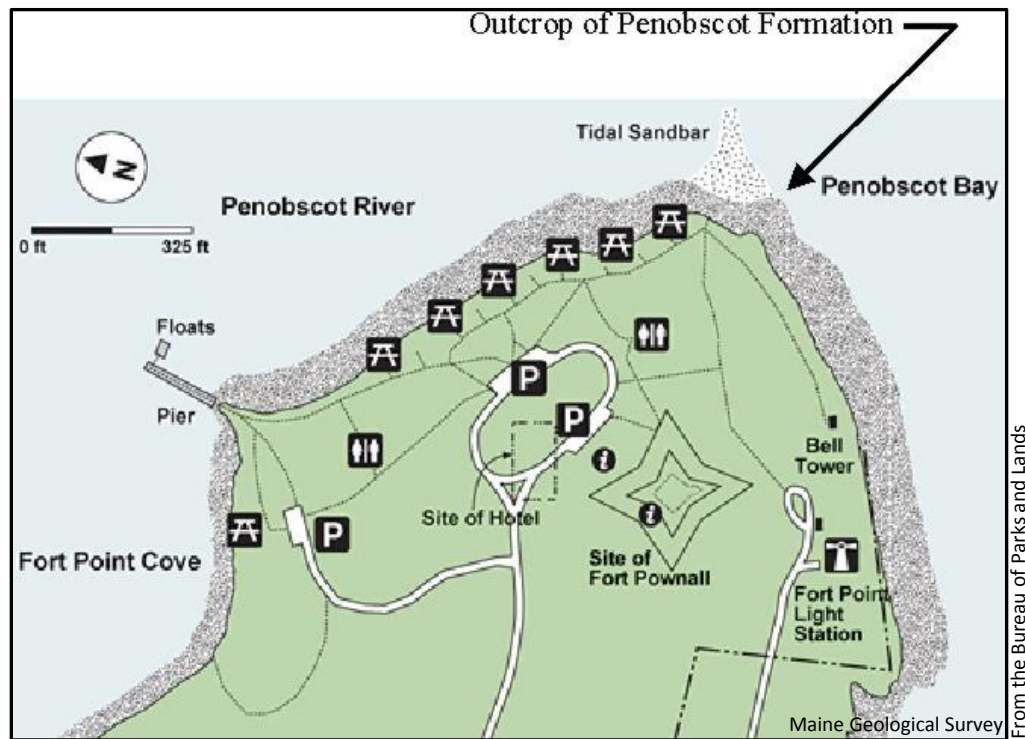


Figure 10. Map of Fort Point State Park showing the tidal sandbar and the location of outcrops of chlorite-grade Penobscot Formation.



The Penobscot Formation at Fort Point State Park, Stockton Springs

The lower portion of the formation contains roughly equal proportions of quartzite and pelitic beds, while in the upper portion pelitic beds dominate roughly 3:1. The metamorphic grade of the Penobscot Formation also decreases from sillimanite grade at the Penobscot Narrows bridge site to chlorite grade at Fort Point State Park 6 miles to the south (Figure 2). There is a good exposure of the Penobscot Formation at chlorite grade (Figure 11-12) at the south end of the tidal sandbar in the park (Figure 10).



Figure 11. Outcrop of chlorite-grade Penobscot Formation at Fort Point State Park. Pelitic beds are more abundant here than at the approach to the bridge, and a crenulate slaty cleavage is well developed.

The Penobscot Formation at Fort Point State Park, Stockton Springs



Photo by Marc Loisel

Maine Geological Survey

Figure 12. Close-up of slaty cleavage in the Penobscot Formation at Fort Point State Park.



The Penobscot Formation at Fort Point State Park, Stockton Springs

The cleavage in the pelitic beds is tightly folded in a variety of orientations while the more competent sandstone beds are more gently folded and have broken and separated in many places (Figure 13).



Photo by Marc Loiselle

Figure 13. Folded and broken quartzite bed in pelitic matrix of the Penobscot Formation at Fort Point State Park.

The Penobscot Formation at Fort Point State Park, Stockton Springs

Finally, lift your gaze from the outcrop and look to the north and you will see the twin towers of the Penobscot Narrows Bridge (Figure 14).



Photo by Marc Loisel

Maine Geological Survey

Figure 14. Looking north at the Penobscot Narrows Bridge from Fort Point State Park.



References and Additional Information

- Hitchcock, Charles H., 1885, Geology, in Colby's Atlas of the State of Maine: George N. Colby & Co., Houlton, Maine, p. 14-17.
- Hussey, Arthur M., II, Chapman, Carleton A., Doyle, Robert G., Osberg, Philip H., Pavlides, Louis, and Warner, Jeffrey (compilers), 1967, Preliminary geologic map of Maine: Maine Geological Survey (Department of Economic Development), scale 1:500,000.
- Keith, Arthur, 1933, Preliminary geologic map of Maine: Maine Geological Survey, issued as Supplement to Leavitt, H. W., and Perkins, E. H., 1935, A survey of road materials and glacial geology of Maine, Volume II - Glacial geology of Maine: Maine Technology Experiment Station, Bulletin 30, vol. 2 (scale 1:1,000,000).
- Osberg, Phillip H., Hussey, Arthur M., II and Boone, Gary (editors), 1985, Bedrock geologic map of Maine: Maine Geological Survey (Department of Conservation), scale 1:500,000.
- Stewart, David B., 1998, Geology of northern Penobscot Bay, Maine, with contributions to geochronology by Robert D. Tucker: U. S. Geological Survey, Miscellaneous Investigations Series Report I-2551, 2 sheets.
- Smith, G. O., Bastin, E. S., and Brown, C. W., 1907, Description of the Penobscot Bay quadrangle, Maine: U. S. Geological Survey, Geologic Atlas, Folio 149, 14 p. (scale - 1:125,000).
- Tucker, R.D., Osberg, P., and Berry, H.N., IV, 2001, The geology of a part of Acadia and the nature of the Acadian Orogeny across central and eastern Maine: American Journal of Science, v. 301, p. 205-260.
- West, David P., Jr., Guidotti, Charles V., and Lux, Daniel R., 1995, Silurian orogenesis in the western Penobscot Bay region, Maine: Canadian Journal of Earth Sciences, v. 32, p. 1845-1858.

